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NEUROMAGNETIC INVESTIGATION OF WORKLOAD AND ATTENTION
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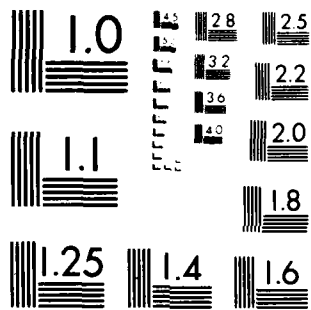
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Progress was made in the areas of instrumentation and techniques, and experiment on the auditory and visual neuromagnetic counterpart to the "P300" complex, and in formulating new approaches to the study of brain activity related to workload and attention. A new system (MAGSCAN), which will be used to hold a multisensor array of SQUID's and gradiometers was designed and is under construction. MAGSCAN		

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BLOCK # 20 - ABSTRACT

will make possible the rapid measurement of the field normal to the scalp, and thereby allow an efficient and cost-effective construction of field maps that are needed for locating sources of neuromagnetic fields. This system will minimize effects of long-term changes in the state of a subject in the course of an experiment. Also, several computer programs were developed to implement experiments and provide a more sophisticated level of data analysis.

An "odd-ball" experiment was conducted in which auditory as well as visual stimuli were employed. Field reversals for auditory odd-balls were not observed over the temporal cortex, as reported by other groups. Thus far the results are consistent with the earlier finding that the source of the P300 complex is in or near the hippocampal formation.

Electrical recordings of P300 were made to verify an earlier finding that components of the event related potential modulate background EEG activity. It is proposed that this modulation wave (which does not appear in the average ERP) reflects cortical activity related to the onset and offset of P300. If this hypothesis is correct, then it should be possible to identify different neuromagnetic sources of P300 and of the modulation wave, with the latter being cortical in origin and the former sub-cortical. Such cortical activity may well reflect cognitive processes and be related to the so-called psychological refractory period.

An experiment was designed jointly with Emmanuel Donchin of the University of Illinois in which our two laboratories will collaborate. A paradigm was developed to insure large P300s that differ in latency and complexity depending upon the difficulty of a visual detection task. We plan to test the hypothesis that different waveforms are attributable to different sources.

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April 22, 1983

Attn of: PKD (202)767-4994

Subject: Contract F49620-82-K-0014, INTERIM SCIENTIFIC REPORT
"Neuromagnetic Investigation of Workload and Attention"

This report on our progress during the first year of the neuromagnetic study of workload and attention summarizes activity in three areas. These are progress in instrumentation and techniques for accomplishing our goals, progress in the conduct of experiments, and new developments that will affect subsequent progress.

1. Instrumentation and Techniques

Our main goal in this project is to identify and localize regions of the brain whose activity reflects the state of a human subject and differentiates among the degree and kinds of activity in which he or she is engaged. The event related field (ERF) was chosen as the physiological indicator because of its ability to resolve different sources in the brain. This resolution is now on the order of 2 or 3 mm in three dimensions. To fully exploit this method it is necessary to conduct experiments more efficiently than was possible in the past. We will soon achieve a much higher level of efficiency by deploying a new system in which five dc SQUID sensors are used simultaneously to detect the ERF external to the scalp. This new system, which was funded by ONR, includes four rf SQUIDS to monitor ambient field in X, Y, Z, and field gradient along the Z axis for purpose of noise cancellation. The outputs of these four channels and their time derivatives will be combined in various ways with the outputs of the ERF sensors to permit a much improved signal-to-noise ratio in a noisy laboratory or operational environment. Since this system will be employed on the Air Force project as well as on Navy projects, we have designed a system holder for use on the Air Force project that will permit rapid scanning of the head (MAGSCAN). In addition, we have been conducting experiments with an rf SQUID system constructed in our laboratory to determine if two SQUIDS at different positions in the laboratory can be effectively used for software cancellation of common mode noise. This has proven to be very successful in the low-frequency portion of the spectrum, where we encounter high levels of $1/f$ noise. This has proven to be a limiting factor in the past. It now seems likely that we will be able to make measurements down to dc field levels without recourse to a shielded environment.

Computer programs designed to implement our experiments have undergone extensive development since the inception of this project. We have gone beyond the simple "odd-ball" paradigm and have programs allowing considerable flexibility in the manner in which both visual and auditory stimuli may be presented. In addition, we also have the capability for recording raw ERF data on digital tape for subsequent analysis and editing of single trials. Furthermore, programs are now available for a more sophisticated analysis of field patterns about the head to determine the degree to which they are consistent with field patterns associated with an ideal current dipole source.

2. Experimental Results

The major results obtained thus far relate to the P300 complex associated with auditory as well as with visual stimuli. This is a follow-up to our finding in the visual domain that the source of the P300 complex is in or near the hippocampal formation. Since the auditory P300 typically occurs about 100 ms prior to the visual P300, it is possible that it has a different source. The

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most suggestive evidence of this is based on results obtained at UCLA by Jackson Beatty and his colleagues (personal communication) who report a reversal of ERF polarity over the auditory cortex. If this finding is confirmed it would mean that at least a portion of the auditory P300 is cortical rather than subcortical in origin.

To test this idea we have implemented an experiment in which the subject anticipates whether a highly probable or highly improbable stimulus will appear on a forthcoming trial by depressing one of two buttons. Then the stimulus is presented with one of two possible outcomes, i.e., confirming the prediction or disconfirming it. We then analyze responses for confirming frequent and infrequent stimuli and for disconfirming frequent and infrequent stimuli separately. All four types of responses are measured both electrically (between Pz and mastoid) as well as magnetically. The ERFs are measured at many places about the head.

We have screened many subjects to obtain a subset of subjects that give large P300s. This makes it possible to map the ERFs with an optimum signal-to-noise ratio. (This should prove to be unnecessary with our new system which is inherently better in this regard). Of course, ERFs to visual as well as auditory stimuli are being measured, since we want to compare the relevant field maps for differences in terms of position of the source or sources.

Thus far we have been unable to confirm the UCLA finding since we have not encountered any field reversals at or near the positions at which they are reported. The data accumulated using both visual and auditory stimuli indicate strong fields over the temporal cortex, with reversals of polarity only for early (N100 and earlier) components of the auditory response across the lateral sulcus. These are undoubtedly sensory components. The later components (later than 200 ms) vary in amplitude with the "surprisal" of the stimuli and thus far seem to have the same scalp distribution for both visual and auditory events. These extensive measurements are still going on, but it appears as though the sources of both visual and auditory P300s are very close to each other, if they are not the same.

This experiment has preceded by other variants on the odd-ball paradigm, but these were discarded because of the adaptation of the subject to the surprise value of stimuli over the very large number of trials needed to complete a field map.

3. New Developments

Progress has been made on two fronts in this project. First we have worked extensively with Emmanuel Donchin of the University of Illinois in the design of a study that would reveal the similarity of sources of P300 that differ in latency and waveform because of experimental manipulations. This was done on two occasions. On one, Dr. Donchin visited our laboratory and we spent a full day working out the implications of various alternative experiments conducted in his laboratory using electrical measurements. Then one of us visited Donchin's laboratory to observe experiments and continue the planning procedure. We decided to use a variant on an experiment conducted by McCarthy and Donchin and implement it on the University of Illinois Pearl System. If funding can be obtained for the shipping of a Pearl system and travel expenses for various personnel (to be described in a forthcoming proposal), then we shall be able to complete this phase of the project. In the meanwhile, and with current funds, we will complete a pilot study this summer at NYU with Dr. Conshin's collaboration. The paradigm will insure large P300s (which are often visible in raw records), and latency as well as complexity of the P300 complex varies considerably, depending upon the difficulty attendant upon detecting a particular item in a visual display. This will provide the best chance for identifying P300 complexes that have different and possibly multiple sources.

The second development is far more subtle in that it is related to the question of the functional relationship between activity of the limbic system before, during and after the part of the P300 complex and other cognitive processes. It may well be that the refractory psychological period encountered in human information processing experiments is related to such activity because the short term memory buffer is occupied in some facet of a cognitive task and is not available at that time for other activity involving a particular psychological resources. We hypothesize that this is reflected by the presence of a signal or signals from the limbic system to one or more regions of the neocortex. Further, this signal may well serve to attenuate the gain of particular sensory and motor (speech) areas. These considerations led us to postulate the modulation of EEG activity originating in these cortical areas and the degree and timing of this modulation would covary with P300. Pilot electrical data suggest the presence of this modulation, as well as earlier work by Kaufman and Locker (1970) and by Spekraisje (1980). However, its significance was not understood in the earlier work since it was interpreted as reflecting only a non-linear interaction of cortical activity. We now feel that this could open the door to a deeper understanding of interactions of activity originating at different locations and depending upon workload and state of attention.

